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ORIGINAL PAPER

Plant nutritional and environmental aspects of organic apple production in East Hungary

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Abstract – The recent surge in interest in fruit growing without the use of agrochemicals in order to safeguard environmental and human health has led to increased awareness of organic fruit production (OFP). Despite the widespread use of the method, there is little information on its nutritional aspects, especially in Hungary. Therefore, the aim of this three-year study was to investigate the nutrient status in an organic apple management system and the impact of nutrient applications on nutrient uptake and on the environment. The research was undertaken at the orchard Fruit Research Station of the University of Debrecen in Debrecen-Pallag, Hungary, during 2009-2011. Three cultivars ('Reanda', 'Rewena', and 'Retina') were selected for the study. In the plantation, only organic manure was applied (stable manure, 30 t ha^{-1}, in 2007). The effect of organic methods was monitored by soil and leaf analyses, as well as field observations. Leaf analysis results indicated significantly lower N, K, Mn, Cu and Zn content in cultivar 'Retina' than in 'Reanda' and 'Rewena'. Results suggested that mobility and availability were unbalanced and obstructed, especially in the case of Ca. The study also demonstrated that the lower nutrient content of soil and also the generally poorer uptake of Ca and Zn in organic apple orchards resulted in higher production risks as compared with conventional or integrated ones. We conclude that a more balanced and more efficient nutrient supply system is needed for organic farms in order to achieve good quality and profitable yield.

Keywords – apple, organic production, fruit nutrition, plant and soil analysis

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Introduction

The total organic area in the EU-28 (i.e. the area fully converted to organic production and area under conversion) was 11.1 million hectares (ha) in 2015 and it is expected to grow in the coming years. The increase in area between 2010 and 2015 was 21 % (Eurostat, 2016). This means earlier predictions that sustainable and environmentally-benign farming practices will come to dominate the entire fruit growing sector in Europe may be realized (Sansavini, 1990; Sansavini, 1997; Morris and Winter, 1999).

Fortunately, in the last decade, the importance of environmentally friendly growing technologies, site oriented fertilization and ecological approaches to apple-growing have been continuously increasing (Nagy, 2012). This trend is also evident in Hungary (Nagy, 2016). However, the nutrition management used and nutritional information base to describe this growth is either incomplete or inaccessible, and sometimes inaccurate. Moreover, organic production systems require a holistic approach in agricultural ecosystem management. A major component of organic production is providing organic sources of nutrients to promote plant growth as well as sustain soil quality. The organic nutrition of plants can present opportunities and challenges to the grower attempting to achieve these aims (Rosen and Allan, 2007).

Organic orchards should be sited on land with superior soils and good pre-plant soil preparation to increase organic matter and correct any sub-optimal soil characteristics. Soil and leaf chemical analysis both play an important role in achieving successful organic fruit growing in fields where nutrient deficiencies or imbalances frequently occur.

It may be necessary to use a nutrition strategy to supply mineral nutrients over the lifetime of the orchard. The slower, natural methods of such an approach require a management approach that is patient as well as dynamic.

In addition, organic production systems strive for sustainability by minimizing environmental degradation and improving soil quality, while maximizing productivity as well as economic returns (Reganold et al., 2001).

Materials and methods

The study was performed at the orchard Fruit Research Station of the University of Debrecen at Debrecen-Pallag, Hungary, during 2009-2011. The 1 ha orchard was planted in 1997 with 39 apple cultivars, grafted on M26 rootstock. Spacing between and within rows was 4 x 1.5 m. Cultivars were planted in 7-tree plots and replicated three times in an organic management system, which consists of 8 rows, labelled from A to L per line. The positioning of the three selected cultivars ('Reanda', 'Rewena' and 'Retina') was arbitrary. In the plantation, only organic manure was applied (stable manure, 30 t ha^{-1}, in 2007). To study the effect of organic management, soil, and leaf analyses as well as field observations were implemented.

Soil sampling and preparation

To establish the actual nutrient supply of the soil in the area under study, chemical soil properties were measured.

Three soil samples were taken from each plot: one from the middle and one from both edges of the plots by leaving 1 m at both sides. As the root system was most concentrated in the upper layer of the soil, soil samples were taken from 0-20 cm layers of the soil by using manual soil sampling equipment as described in Jackson (1958) using the Hungarian standard method MSZ-08 0202-77. Sampling was performed at the beginning of the vegetation period in April in 2010. The samples were dried, sieved, homogenized and stored in plastic boxes until the examination. Soil pH was determined from a soil solution of 0.01 M $CaCl_2$. Plasticity index (K_A) and humus content were measured according to Hungarian guideline (Hungarian Standard MSZ 20135:1999). Nitrogen forms of each soil sample were quantified according to Houba et al. (1986). For extracting the available P and K content of soils, ammonium-lactate solution (so-called AL extractant) was used and the amount of phosphorus was quantified colorimetrically with the phospomolybdovanadate method (Hungarian Standard MSZ 20135:1999).

Potassium content was quantified by flame atom emission spectrophotometry (Hungarian standard MSZ 20135: 1999). For determining Ca, Mg, Mn, Cu and Zn contents of the soil Lakanen-Erviö solution (LE) was used (Lakanen and Erviö, 1971). Soil Ca, Mg, Mn, Cu and Zn contents were quantified using flame atomic absorption spectrophotometry (Hungarian Standard MSZ 20135: 1999). Soil and leaf samples were analyzed in the laboratory of the Institute of Environmental Sciences, Karoly Robert College, Gyongyos, Hungary.

Leaf sampling and preparation

The selected cultivars from the same tree plots were used for plant sampling. Leaves were taken from all trees from the plots at the standard sampling time (the second half of July). For sampling, 8-10 healthy, well-developed leaves were taken from the mid-third portion of extension shoots of the current year as described in the international and Hungarian plant sampling guidelines for fruit orchards (Stiles and Reid, 1966; Hungarian standard MI-08 0468-81).

Leaf samples were dried, finely ground (< 1 mm) using a Polymix PX-MFC 90D grinder (Kinematica, Luzern, Switzerland) and homogenized. Samples were then stored in paper bags in a dark and dry place until use.

For determining the nutrient contents of leaves, first homogenized leaf samples were digested with cc. 5 ml H_2SO_4 and 5 ml H_2O_2 in a heating block digester at 220 °C for 2 h. The digested samples were diluted with distilled water to 100 ml. The nutrients were determined in this solution and the results calculated as percentages of the determined element relative to the dry weight. For reference values, dry matter analysis was also performed on leaves after harvest.

Leaf nitrogen contents were determined by the Kjeldahl method, using a UDK 142 distillation system (VELP Scientifica, Bohemia, NY, USA) (Benton Jones et al. 1991). Leaf P was quantified colorimetrically with the phospomolybdovanadate method using a VIS SP-850 Plus spectrophotometer (Metertech Inc., Taipei, Taiwan).

Leaf K content was determined by flame atom emission spectrophotometry and Ca, Mg, Mn, Cu and Zn contents of the leaves were quantified by the flame atomic absorption method as described above for the soil samples.

Statistical analysis

All the obtained data were tabulated and statistically analyzed according to Svab (1981) using the L.S.D. test at 5% level to recognize the significance of the differences between various treatment methods. The effects of the different treatments were assessed within ANOVA and Fisher's least significant differences were calculated following a significant ($P \leq 0.05$) F test.

Results and discussion

Soil analysis

At the beginning of the study, an analysis of the orchard soil was undertaken in order to determine some general information about its nutrient status.

The main properties of the soil in the area under study are shown in Table 1.

The orchard soil type was brown forest soil with an alternating layer of clay “Kovarvany” which is a silicate strip with a high humus and Ferro content and which plays a great role in water retention. The soil is relatively poor in colloids, macronutrients and humus content (Table 1). The soil plasticity index according to Arany (K_A) was 28. The salinity of the soil was approx. 0.002%. The orchard soil type was slightly acidic, non-calcareous sandy soil with very low humus content. The water capacity of the soil was low according to the type.

The texture grade of the soil was determined as sandy based on its plasticity index (K_A) (Table 1).

Table 1. Results of soil analysis (19.04.2009; Pallag, Hungary)

Parameters	Value
K_A*	28
pH (0,01 M $CaCl_2$)	5.17
Humus (%)	0.78
NO_3^- -N (0,01 M $CaCl_2$) (mg/kg)	1.14
NH_4^+-N (0,01 M $CaCl_2$) (mg/kg)	0.87
Organic N (0,01 M $CaCl_2$) (mg/kg)	2.90
PO_4^{3-} (0,01 M $CaCl_2$) (mg/kg)	4.76
K (0,01 M $CaCl_2$) (mg/kg)	178
Ca (LE) (mg/kg)	442
Mg (LE) (mg/kg)	89.7
Mn (LE) (mg/kg)	66.3
Cu (LE) (mg/kg)	3.98
Zn (LE) (mg/kg)	2.14

Our results show that the soil pH was slightly acidic, optimal for apple growing (MEM NAK 1981). Carbonate content in the soil was not detectable.

Humus content and mineralized N forms, like nitrate and ammonium nitrogen and soluble organic N in the soil were low, which was in accordance with the results of yields and soil type.

The rate of mineralization was slow and the N supply of soil was weak.

Moreover, larger amount of easily soluble organic N fraction indicated that organic production can be used in sandy soils provided that the efficiency of nutrients is increased by improving soil properties.

Easily soluble soil phosphate concentrations were low but the available dissolved K content was satisfactory for apple growing.

Micronutrient contents were very low in the topsoil of the organic orchard with the exception of copper. This is probably due to more frequent copper usage (as a fungicide) in an organic orchard than in an integrated one.

Our results showed that the seasonal variability of available elements in the soil was high in the organic orchard (data not shown). The data on micronutrient contents correspond to the values characteristic to sandy soil with low humus content and pH value.

Soil analytical results corresponded to the nutrient maintaining of organic fruit production. The data obtained demonstrated that organic farming when undertaken in unfavorable conditions requires more than simple organic fertilization. The required yield can only be achieved by improving soil nutritional management.

Plant analysis

Based on the leaf diagnostic results it was established that the dynamics of macro and microelement uptake of examined cultivars (data not shown) was not impacted on by the adopted growing regime.

N and K contents of the leaves were optimal and their amount was significantly lower in ‘Retina’ than in the other cultivars (Table 2). Leaf phosphorus content was at two times the optimal level. Its amount the highest for ‘Retina’ had the highest levels but there was no significant difference observed between cultivars.

This can be explained by the use of organic manure when the orchard was established.

Leaf Ca was lower than the optimal value which can be explained by the soil properties and the lack of Ca supply.

Leaf Mg was in the optimal range and not affected significantly by cultivars (Table 2).

Leaf Mn, Cu and B were optimal while the Zn concentration in the leaves was lower than the optimal value. The amount of Mn in the leaves is a result of the soil conditions in the orchard. Acidic conditions promote the solubility and thereby the uptake of Mn. The Cu content of the leaves was also in the 'optimal' range an effect of the relatively high Cu content of the soil resulting from the frequent use of copper sprays ($CuSO_4$) against diseases and pests (Holb et al., 2009). The low Zn content of the apple leaves is the result of the poor availability of soil Zn (Table 1). Overall, the results of the leaf analysis are consistent with the soil measurements. The low nutrient status of microelements in the leaves is a consequence of the low availability of these nutrients in the soil.

Table 2. Nutrient contents in apple leaves
(Pallag, averages of 2010-2011, at the standard sampling time)

	Reanda	Rewena	Retina	Optimal
N (%)	2.61b	2.61b	2.51a	2.1-2.3
P (%)	0.26a	0.27a	0.29a	0.12-0.13
K (%)	1.47b	1.42b	1.20a	1.2-1.6
Ca (%)	1.00b	0.88a	0.83a	1.5-1.8
Mg (%)	0.36a	0.37a	0.38a	0.25-0.40
Mn (mg/kg)	78.02c	78.96c	54.18a	40-150
Cu (mg/kg)	9.02c	9.02c	6.82a	5-20
Zn (mg/kg)	16.60b	16.30b	13.10a	25-50
B (mg/kg)	29.85b	27.14a	26.84a	25-50

In each column, means followed by the same letter are not significantly different ($P<0.05$).

Beside absolute element concentrations, their binary ratios were also investigated (Table 3.). My assumption is that these ratios can provide a better indication of nutritional status than conventional sufficiency range approaches. It has been suggested that using these ratios minimize the effects of dilution or concentration due to dry matter and age factors and allow for a better evaluation of possible nutritional interactions. The most frequently used ratios (N/K, N/P, N/Ca, K/ Ca, K/Mg, Ca/Mg and Cu/Zn/Mn) were calculated (Table 3.).

Table 3. Nutrient ratios in apple leaf
(Pallag, 2009-2011, averages of cultivars at the standard sampling time)

Nutrient ratios	Organic	Optimal
N/K	1.89	1.76
N/P	9.42	14.40
N/Ca	2.85	1.53
K/Ca	1.51	0.87
K/Mg	3.68	3.90
Ca/Mg	2.44	4.50
Cu/Zn/Mn	~1:2:9	~1:3:10

Some nutrient ratios (N/P, N/Ca, K/Ca) were unfavorable in the organic orchard, which highlighted the less than optimal nutrient supply conditions in this part of the orchard (Table 3.).

For example N/Ca, K/Ca and Ca/mg ratios indicated that the Ca uptake by the trees was limited leading to a relative Ca deficiency (Photo 1) in the orchard in spite of the large amount of soil Ca.

Furthermore, direct evidence was found that the applied plant protection practice had an effect on nutrient uptake which subsequently impacted on the ratio of nutrients in leaves. Due to the higher leaf Cu content in organic apple leaves, its proportion in the Cu/Zn/Mn triple ratio was higher than the optimal value (Table 3.).

Figure 1. Apple showing classic signs of Ca deficiency

Conclusions

In conclusion, the obtained leaf analytical results vary across the three cultivars. Significantly lower N, K, Mn, Cu and Zn content was measured in 'Retina' than 'Reanda' and 'Rewena'.

Our results suggest that the mobility and availability of nutrients in the organic orchard under study, was unbalanced and obstructed, especially in regards to Ca. This study also demonstrated that the lower nutrient content of the soil as well as the generally poorer uptake of Ca and Zn in organic apple orchards resulted in a higher production risk compared with conventional or integrated systems. This indicates that in order to ensure a good quality crop and a profitable yield a more efficient nutrient supply is needed for the organic management system.

Moreover, from these results it would be foolhardy to state that organic fruits provide greater health benefits than those produced in integrated or conventional operations, but we suggest that these comparison studies should be expanded. The real benefit of these studies is that they can identify and establish the production input weaknesses and strengths that affect nutrition, so that changes can be made to improve both organic and integrated fruit production technologies.

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